COBRA Main Engine Project

NAS8-01108

AIAA/IAF Symposium on Future RLV's

12 April 2002

Jim Snoddy
Steve Sides

2nd Generation RLV

Pratt & Whitney
A United Technologies Company

NASA

P&W-Aerojet Propulsion Associates
(A Joint Venture)

COBRA MAIN ENGINE PROJECT TEAM NAS8-01108/01083
PRATT & WHITNEY - AEROJET PROPULSION ASSOCIATES

2nd Generation RLV

NASA Project Manager/COTR
721-26-20
Jim Snoddy/UP30
(256) 544-4972 Cell (256) 651-3700

Resident Office
@ West Palm Beach
Bill Powell/UP30
(561) 796-6132 Cell (561) 236-1560

Assistant Project Manager
Randy Forsythe/UP30
(256) 544-2456

Lead System Engineer
Tom Byrd/UP30
(256) 544-7147

Project Office Support

Management Support Assistance
Amyrebecca Shockley/Infinity
(256) 544-4997

Engine Systems Manager
Kathy Kynard/UP30
(256) 544-7439
721-26-22

Reliability and Operations Manager
Rick Christenson/UP30
(256) 544-8608
721-26-21

Powerhead Manager
Eric Tepool/UP30
(256) 544-3198
721-26-23

Thrust Chamber Assembly Manager
Mike Shadoan/UP30
(256) 544-5276
721-26-24

Contractor Project Manager
Rick Bachtel/Pratt
(561) 796-9067

Assistant Project Manager
Steve Sides/Pratt
(561) 796-2611

Deputy Project Manager
Dick Johnson/Aerojet
(916) 355-4622

Chief Engineer
Tom Kmiec/Pratt
(561) 796-4059

Deputy Chief Engineer
Scott Sieger/Aerojet
(916) 355-3353

Pratt Regional Manager
Huntsville/Vic Giuliano
(256) 721-2422

Aerojet Director Space Propulsion
Huntsville/Carla Bossard
(256) 837-3982

Independent Review
Lee & Associates
(256) 852-7336

Glenn Research Center
Insight
Margaret Tuma
(216) 433-8665

Stennis Space Center
Insight
Rick Gilbrech
(288) 688-3548

Shuttle Project
Insight
Mel Bryant
(256) 544-0825

ROADMAP - NRA 8-27 THROUGH NRA 8-30 AND BEYOND

2nd Generation RLV

<u>Team Background</u>
SSME Studies
XLR129
RL10 Family
Titian Propulsion
ALS/NLS
DC-X, DC-XA
SSME-AT
X-33 Activity
IHPRPT
EELV
SMV/SOV
International
STAS 3B Results

→

<u>NRA 8-27 Vehicle Primes</u>
Boeing
Lockheed Martin
Kelly Aerospace
Orbital Sciences
Space Access
Andrews Space

→

<u>Initial</u>
<u>2GRLV Engine Options</u>
DBFRSC
DBFFSC
SBFRSC
SBORSC
SPLTEX
SBFRGG

→

<u>NRA8-27</u>
Contract
NAS8-00168

→

<u>NRA 8-30 'Cycle 1' Candidates</u>
SBFRSC
SBORSC
SPLTEX

↓

<u>NRA8-30</u>
Contract
NAS8-01108

↓

<u>NRA 8-30 'Cycle 1'</u>
SBFRSC -COBRA
SPLTEX-RLX

Phase I
2001-2003
NRA 8-30
Cycle 1 Base & Option

Prototype Design [illegible]
Technology Risk [illegible]
Feasibility Study

←

Phase II
<u>2003-2005</u>

Continued
Risk Reduction
Prototype Engine Test
FSD SRR

←

<u>2005-2010</u>

2GRLV
FSD Program

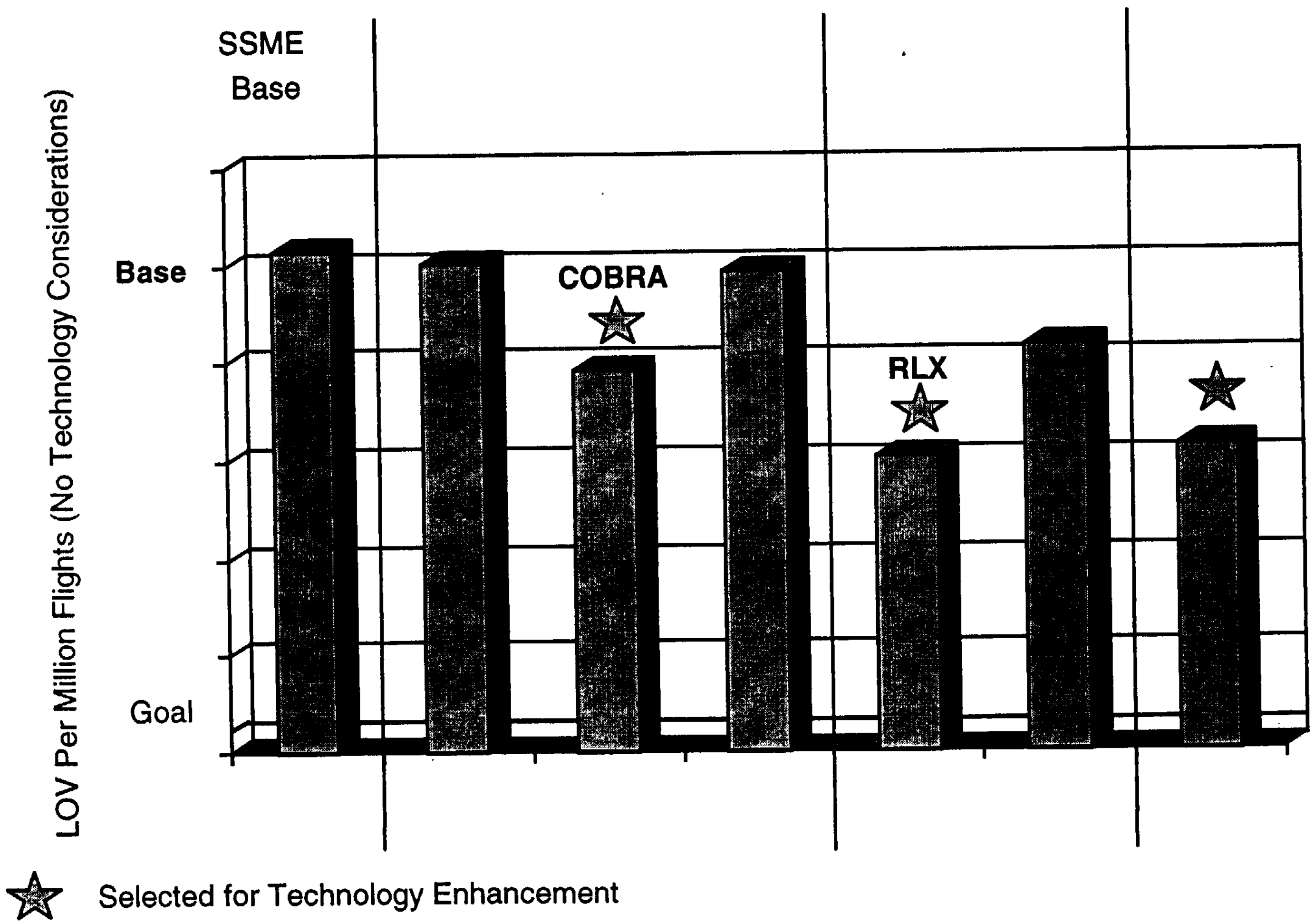
←

<u>2010 Operational 2GRLV</u>

<u>Level I Requirements</u>
[illegible]
[illegible]
Engine [illegible]
[illegible]
Current SSME
[illegible]

DBFRSC - Dual Burner Fuel Rich Staged Combustion (H_2/O_2)
DBFFSC - Dual Burner Full Flow Staged Combustion (H_2/O_2)
SBFRSC - Single Burner Fuel Rich Staged Combustion (H_2/O_2)
SBORSC - Single Burner Oxidizer Rich Stage Combustion (RP/O_2)
SPLTEX - Split Expander (H_2/O_2)
SBFRGG - Single Burner Fuel Rich Gas Generator (H_2/O_2)

COBRA (SBFRSC) AND RLX (SPLTEX) CYCLES SELECTED BASED ON INHERENT CYCLE SAFETY AND 2GRLV NEEDS

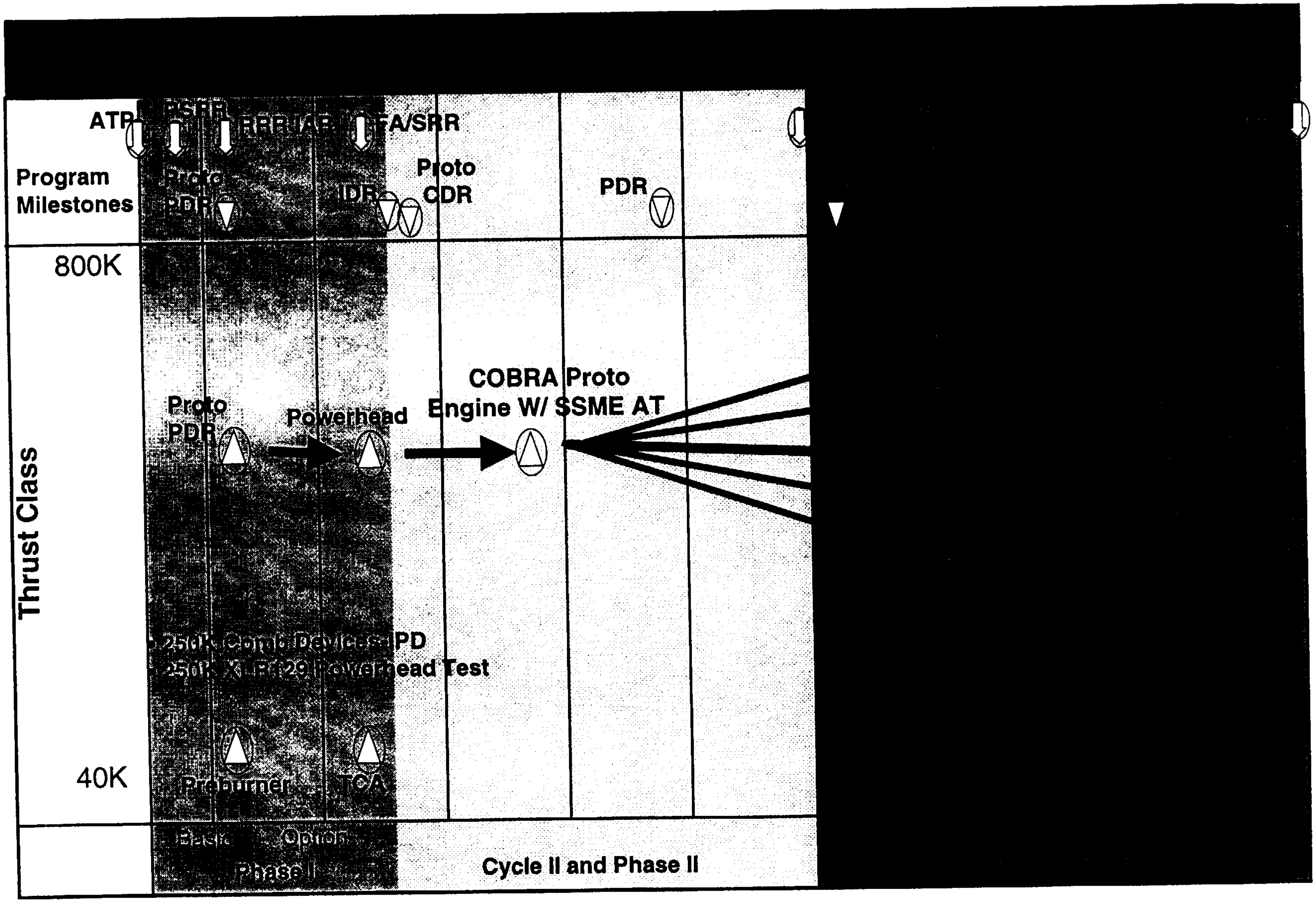


COBRA PROTO-TYPE ENGINE APPROACH ENABLES MISSION SUCCESS

2nd Generation RLV

- **Requirements**
  - Propulsion Systems Requirement Document (PSRD) Traceable to the Synthesized Architecture Requirements (SAR) and both are Full Scale Development (FSD) Requirements
    - **COBRA** Engine Requirements Traceable to PSRD
      - **COBRA** Engine System Proceeding to Configuration Control
        - » SRR Conducted
        - » PDR Conducted
        - » Powerhead Test in Option II
        - » CDR end of Option II
- **Design and Development Approach**
  - **COBRA** Engine System Integrates Risk Reduction Technologies with Engine Cycle
  - **COBRA** Engine System Design Fidelity Enables
    - Engine System Relevant Environments Characterization
    - Risk Reduction Technology Demonstration in a Relevant Environment
    - Engine Reliability Demonstration to Allow Traceability to FSD
    - Engine Operation & Maintenance Demonstration to Allow Traceability to FSD
    - Engine Manufacturing Demonstration
    - Engine Performance Verification at Thrust Level Representative for a Wide Scale
    - Design Process & Control are FSD Applicable (e.g., EEE Parts, Fracture Control, Ops Concept)

COBRA PROVIDES QUICK, LOW COST DEMO OF CYCLE AND TECHNOLOGIES

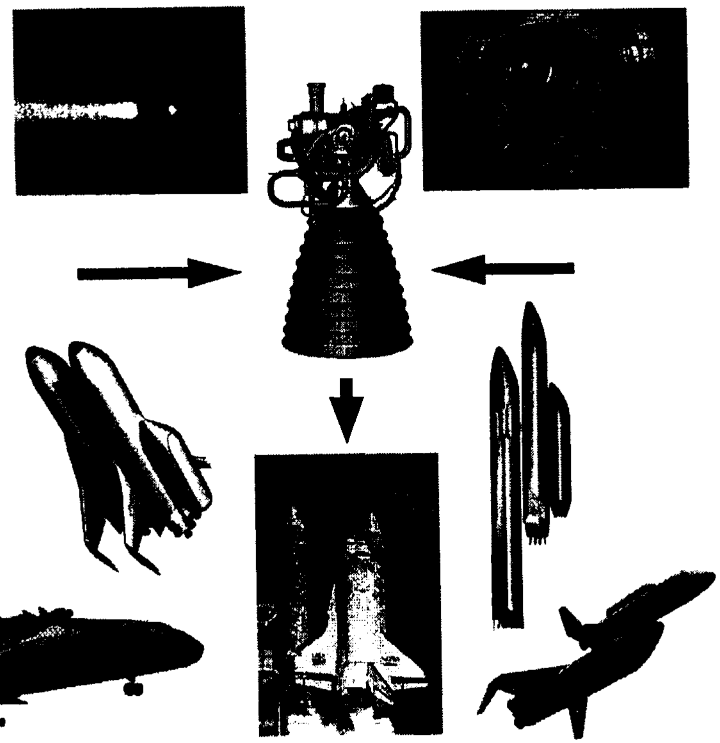


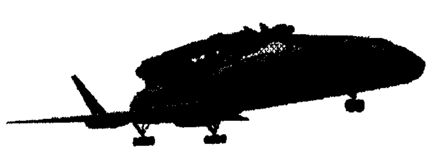
COBRA CYCLE I RISK REDUCTION SUPPORTS TECHNOLOGY NEEDS FOR 2GRLV

<u>C</u>o-<u>O</u>ptimized <u>B</u>ooster for <u>R</u>eusable <u>A</u>pplications

2nd Gen RLV Focus
- Crew and vehicle safety
- Reliability
- Operability
- Maintainability
- Low payload cost

2nd Gen RLV Architectures Supported
- Derived shuttle
- Evolved shuttle
- TSTO





Cycle I Risk Reduction
- Systems engineering
- EHMS architecture/safety sensor)
- Full-scale 600K preburner
- Full-scale 600K main case
- 40K main injector
- 40K main chamber
- 40K LOX-cooled nozzle section
- LOX and fuel boost pumps
- High pressure turbopumps
- Smart valves
- Full-scale nozzle fabrication
- Main LOX valve development
- Lightweight material development
- Integrated powerhead testing
- Main combustion chamber
- Preburner LOX valve

COBRA FEATURES GROUNDED FROM NRA 8-27 STUDY

COBRA Safety

- Single preburner cycle
- Failsafe hot gas system
- Engine Management Health System modeled on successful military jet engines
- Durable combustion chamber
- Elimination of Crit 1 HX failure Mode
- Milled channel nozzle
- Preburner supplies 500 °F cooler turbine gas temperature relative to SSME

COBRA Reusability/Operability

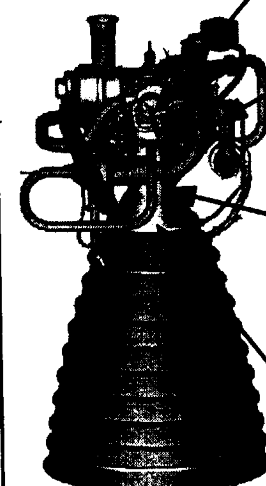
- >100 mission life
- >50 missions between overhaul
- <100 man-hours per flight scheduled maintenance
- <16 hours turnaround between flights

COBRA Specifications

Thrust class	600,000 Lbf*
Weight	8,000 lbm
Specific impulse	450 seconds
Cycle	Staged Combustion
Propellants	Liquid Hydrogen Liquid Oxygen
Mixture ratio	5.5:1 to 6.5:1
Shutdown reliability	0.9995
Catastrophic reliability	0.999995

*Can be scaled 200,000 to 800,000 Lbf

COBRA Risk Reduction Activities



Powerduct main case for lightest weight and fewest hot gas joints

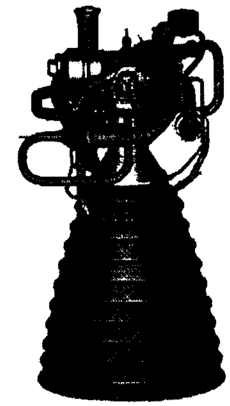
Mature SSME-AT turbopumps increase safety and reduce risk

Main injector reduces touch labor and has no parts which can come loose

Long life Liner

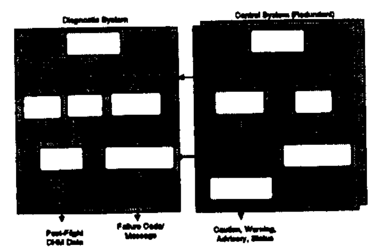
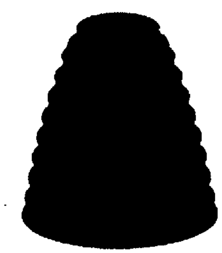
Milled channel regeneratively cooled nozzle ~70:1 adopted from SSME nozzle upgrade

ACHIEVING ENGINE SAFETY

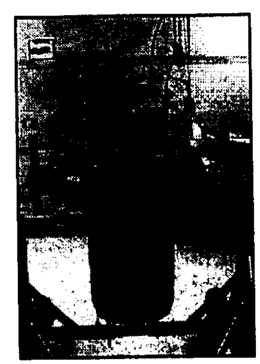
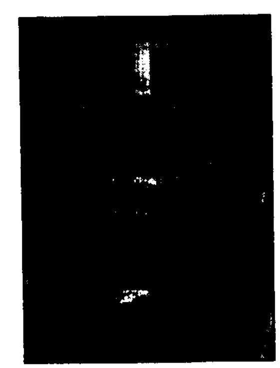


Design for Safety
- Single fuel rich preburner
- Fail safe powerduct
- External heat exchanger
- Cool turbine temperatures

Technologies for Safety
- Advanced engine health monitoring
- Channel wall nozzle
- Combustion Device liners

Maturity for Safety
- Early hardware testing
- Demonstrated technologies
- Mature turbomachinery (ATD)

RLX CYCLE I RISK REDUCTION SUPPORTS TECHNOLOGY NEEDS FOR 2GRLV

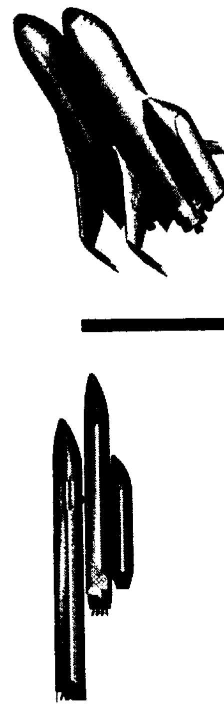
Rocket, Liquid, Expander (RLX) - Split Expander (SPLTEX) Cycle

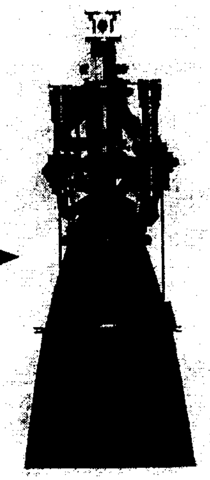
2nd Gen RLV

- Crew and vehicle safety
- Reliability
- Low payload cost
- Maintainability

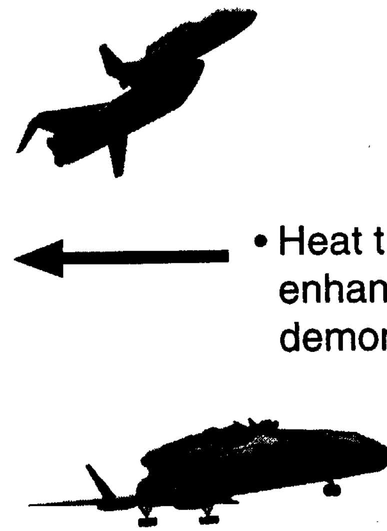
2nd Gen RLV Architectures Supported

- Orbiter
- TSTO (upper stage)





Cycle 1 Risk Reduction



- Heat transfer enhancement demonstration

RLX FEATURES GROUNDED FROM NRA 8-27 STUDY

Generation RLV

RLX Safety
- Simple split expander cycle
- Single combustor
- EHMS modeled after successful military jet engines
- Inherently limiting power cycle

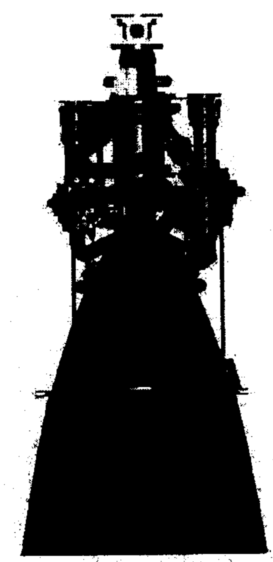
RLX Reusability
- Greater than an order of magnitude improvement in flight safely
- >100 mission life
- >50 missions between overhaul
- Zero hours per flight scheduled maintenance
- <16 hours turnaround between flights

RLX Specifications

• Thrust	300,000 Lbf*
• Weight	4,000 lbm
• Specific Impulse	450 seconds
• Cycle	Expanded
• Propellants	Liquid Hydrogen Liquid Oxygen
• Mixture ratio	5.5:1 to 6.5:1
• Shutdown reliability	0.9995
• Catastrophic reliability	0.999995

*Can be scaled up to 450,000 Lbf

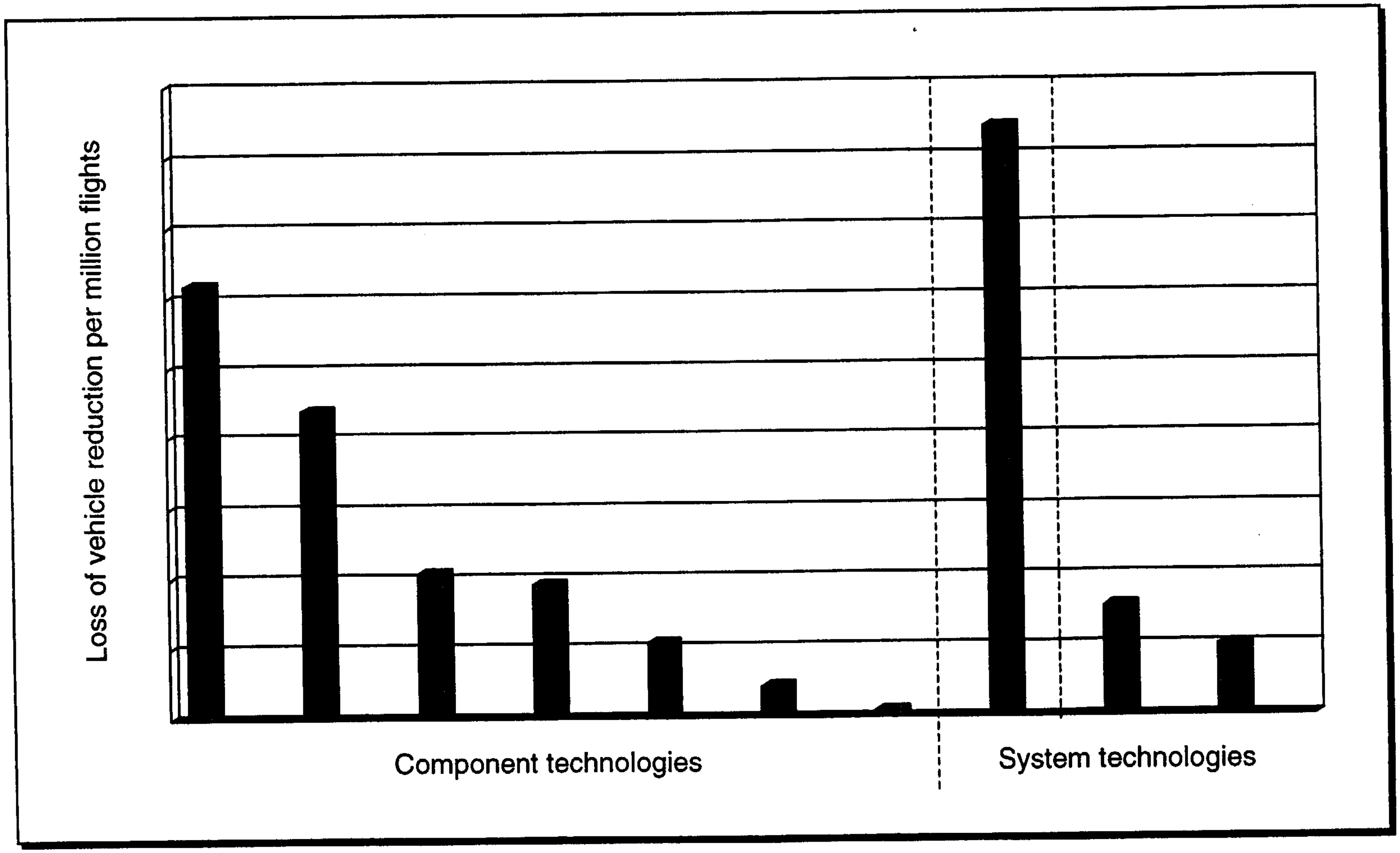
Major RLX Risk Reduction Activities



- Heat transfer enhancement demonstration

NRA 8-30 TECHNOLOGIES ARE ENABLING TO 2GRLV SAFETY GOALS

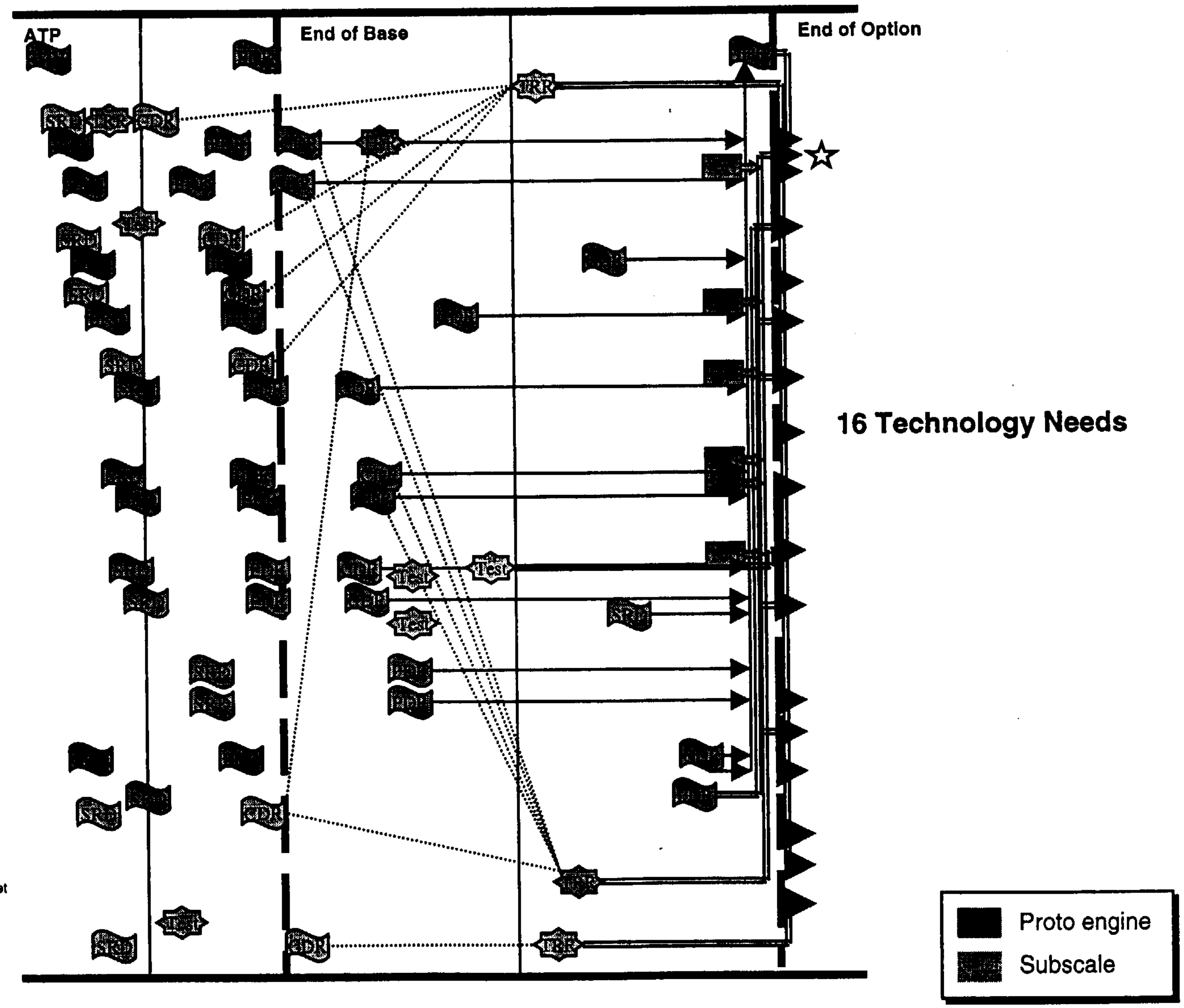
Benefit of **COBRA** Safety Risk Reduction Technologies



NRA 8-30 CYCLE I TECHNOLOGY ROADMAP

2nd Generation RLV

1.4.7 Propulsion
1.4.7.1 Project Management
1.4.7.2 Propulsion Systems Eng
1.4.7.3 Cobra Engine
1.4.7.3.1.1 Prototype & Risk reduction
1.4.7.3.1.1.1 Combustion Devices
1.4.7.3.1.1.1.1 Preburner
1.4.7.3.1.1.1.1.1 Subscale
1.4.7.3.1.1.1.1.2 Proto
1.4.7.3.1.1.1.2 Powerball
1.4.7.3.1.1.1.3 Injector
1.4.7.3.1.1.1.3.1 Unielement
1.4.7.3.1.1.1.3.2 Subscale
1.4.7.3.1.1.1.3.3 Prototype
1.4.7.3.1.1.1.4 Combustion Chamber
1.4.7.3.1.1.1.4.1 Subscale
1.4.7.3.1.1.1.4.2 Prototype
1.4.7.3.1.1.1.4.3 Fabrication
1.4.7.3.1.1.1.5 Nozzle
1.4.7.3.1.1.1.5.1 Subscale
1.4.7.3.1.1.1.5.2 Fabrication
1..4.7.3.1.1.1.5.3 Prototype
1.4.7.3.1.1.2 Turbomachinery
1.4.7.3.1.1.2.1 ATD Modification
LOX
LH2
1.4.7.3.1.2.2.2 Boost Pumps
1.4.7.3.1.1.2.2.1 LOX
Component
Proto
1.4.7.3.1.1.2.2.2 LH2
Component
Proto
1.4.7.3.1.1.3 Controls
1.4.7.3.1.1.3.2 Controller
1.4.7.3.1.1.3.3 Actuators
1.4.7.3.1.1.3.4 Valves
1.4.7.3.1.1.4 Externals
1.4.7.3.1.1.4.2 Plumbing
1.4.7.3.1.1.5 EHMS
Proto
Component
1.4.7.3.1.1.6 Light Weight Material Dev
1.4.7.3.1.1.6.2 Plumbing & Valves
1.4.7.3.1.1.6.3 Chamber Structural Jacket
1.4.7.3.1.1.7 Engine/Subsystem Test
1.4.7.3.1.1.7.1 Powerhead Test
1.4.7.3.1.3 MCC Heat Transfer for RLX
1.4.7.3.1.3.1 Lab. Dev.
1.4.7.3.1.3.2 Subscale Dev/Test
1.4.7.3.1.3.3 Full Scale Dev



COBRA PROGRAM

Aligns Risk Reduction Data with FSD decisions-Uses Building Block Approach